Dewatering of a Large Excavation Pit by Wellpoints

M. U. Ergun
Middle East Technical University, Ankara, Turkey

M. S. Nalçakan
Middle East Technical University, Ankara, Turkey

Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 5.12

Dewatering of a Large Excavation Pit by Wellpoints

M. U. Ergun
Associate Professor of Civil Engineering, Middle East Technical University, Ankara, Turkey

M. S. Nalçakan
Assistant, Civil Engineering Department, Middle East Technical University, Ankara, Turkey

SYNOPSIS An excavation, rectangular in dimensions of 55 m x 95 m at the base and approximately 120 m x 160 m at the ground surface was made possible by the use of multi-staged wellpoint dewatering system. Groundwater table was lowered more than 20 meters using four stage wellpoint system to construct the main wastewater pump station for the city of Izmir.

The most significant soil parameter affecting the planning and design of the dewatering work is the coefficient of field permeability, and it has been directly measured by a large scale pumping test at the site. During dewatering and construction stages, piezometers, inclinometers, extensometers and both conventional surveying and EDM methods were used.

Total discharge rate was measured at different stages and it is compared with the theoretical approaches. Partial penetration factor for the well into aquifer is estimated.

1. INTRODUCTION

The pump station site is located at the North of the Bay of İzmir, and is situated within the alluvial fan area of the Gediz river. The area at the present time is largely undeveloped. Surface conditions throughout the site is similar, and groundwater is approximately one meter below ground surface. The area, though naturally drained by tributaries of the Gediz river, is susceptible to flooding and inundation by surface run-off following the periods of high rainfall.

The pump station was constructed to incorporate two basement levels at 14.74 m and 18.09 m below ground level. Therefore, extensive excavation below ground water level was required during construction. This construction required the groundwater table to be pulled down more than 18 meters to be able to perform the construction in dry.

In this paper, the studies and tests performed in order to design the dewatering system are discussed. The dewatering works and the performance are described. In the first part, presentation is made of the studies related with the prediction of flow and the amount of water to be pumped from the excavation in order to keep the water level lowered until the required depth. In the second part, the description and performance of the adopted design are presented. Finally, the actual values of the recorded pumped flow rates are compared with the predicted ones. A partial penetration factor for the well into aquifer is recommended from this comparison. Different ways of designing a wellpoint dewatering system have been discussed.

2. PRELIMINARY STUDIES, PERFORMANCE OF WELLPOINT DEWATERING SYSTEM AND ESTIMATION OF FLOW

2.1 Preliminary Studies

Soil conditions were investigated by borings to a maximum depth of 50 meters below the ground level. These borings indicated alternating layers of soft and firm clay and medium dense sand underlain by firm clay at 25 to 28 meters. Investigation results showed sandy clay in one of the borings at 22 meters below ground level, clayey and sandy silt at 21 meters in one of the borings, and clay at 28 meters below the ground level in another.

An idealized geotechnical design profile obtained from these borings is presented in Figure 1. Ground conditions and stratigraphy between locations should be expected to vary from the average profile presented in Fig.1. but, these variations were not so large as observed during the excavation.

No matter, how carefully laboratory permeability tests are made, they represent only minute volume of the soils at the site, therefore a field pumping test and piezometric observations were done to obtain the hydraulic parameters.

Drawdown data were obtained from the constant-rate pumping test in the pumping well TW1 and piezometers PH-1, PH-2 and PH-3, the locations of which are shown in Fig.2.

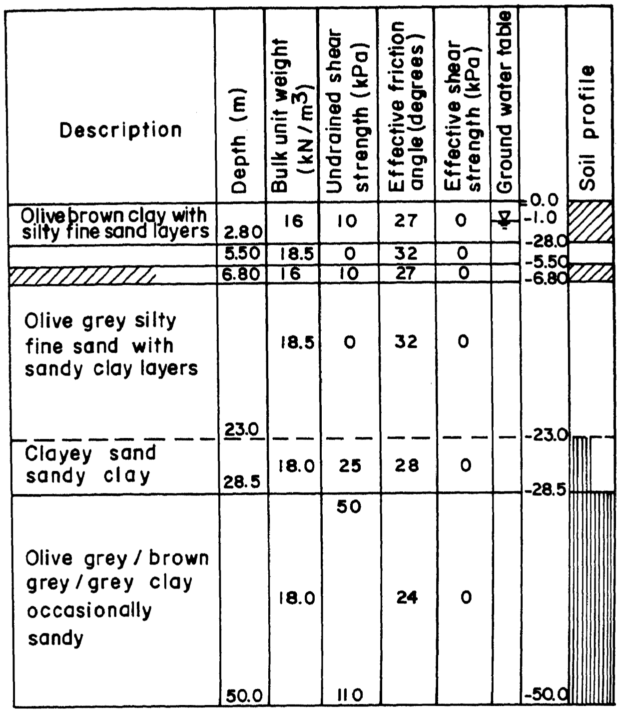

Fig. 1. Geotechnical Idealized Design Profile

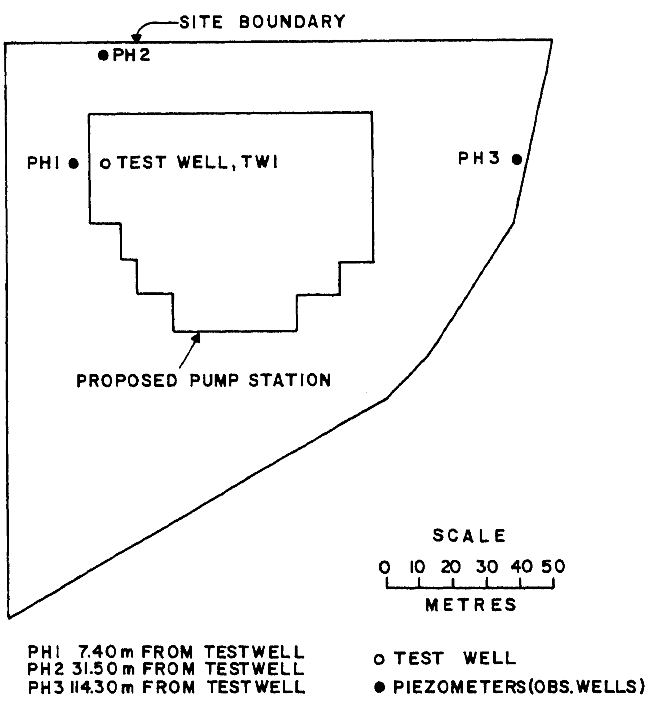

Fig. 2. Site Plan of Çiğli Pumping Station Showing Proposed Location of Test Well and Piezometers

The results of constant-rate pumping test performed in Çigli - İzmir are given in Table 1.

TABLE I. Hydraulic Parameters Estimated from Pumping Test

T_{avg}, Average Transmissivity	: 66.74 m^2/da:
S_{avg}, Average Storativity	: 0.001 dim.le
B_{avg}, Average Aquifer Thickness	: 16.0 m
k, Coefficient of Permeability	: 4.83x10^{-5}m/s

2.2 Wellpoint Dewatering System

The idealized soil profile (Fig.1) shows that vertical wellpoint dewatering system can be applied at this site. Under favorable conditions, the water level can be pulled down in steps of at least five meters by stage-dewatering. Four stage wellpoint dewatering system was used in the Çigli Pump Station excavation to lower the water level 18 meters down with simultaneous excavation.

Wellpoints, 10 m in total length, 7 m long scree: were installed at regular intervals (roughly 1 m spacing) around the perimeter of the each stage of the excavation. The depths of the first thre stages were -2.00 m, -6.50 m,-11.00 m on all sid and -14.74 m and -15.50 m at the fourth stage on different sides (Fig.3). Wellpoints were connected to high vacuum pumps by means of header pipe with couplings and fittings.

It can be seen in the idealized soil profile that all the wellpoints were installed within the depth of the fine sandy soil with sandy clay layers, and the coefficient of field permeabilit estimated from pumping test was 4.83x10^{-5} m/sec. Wellpoints were designed using the nomograms developed for the stratified clean sands and gravels (Mansur and Kaufmann, 1962). Each stage wellpoints are designed as if they are working independently. A wellpoint spacing of about one meter can be selected from the nomogram for a single stage groundwater lowering of 5 m.

Excavation in Çigli was performed in four stages The lengths, the total number of wellpoints, and the number of the pumps working in each stage of the excavation are summarized in Table 2.

TABLE 2. The Total Number of Wellpoints and Pumps in Çigli Pump Station Excavation with the Perimeter Lengths of the Stages.

Stage	Below Ground Level (m)	Length (m)	Total Number of	
			Wellpoints	Pumps
1	-2.00	585	600	4
2	-6.50	460	400	3
3	-11.00	365	354	4
4	-14.44 -15.50	280	270	3

Many piezometers were installed through sections A-A, B-B, C-C, D-D, E-E, and F-F, shown in Fig.3, to determine the position of the groundwater table during dewatering.

Conventional slope stability analyses have been performed for the slopes of the excavation at various stages. Inclinometer and extensometer readings were taken at each side of the excavation in addition to piezometric readings. Conventional surveying of many points on the slopes were also made. The locations of the instruments are shown in Fig.3.

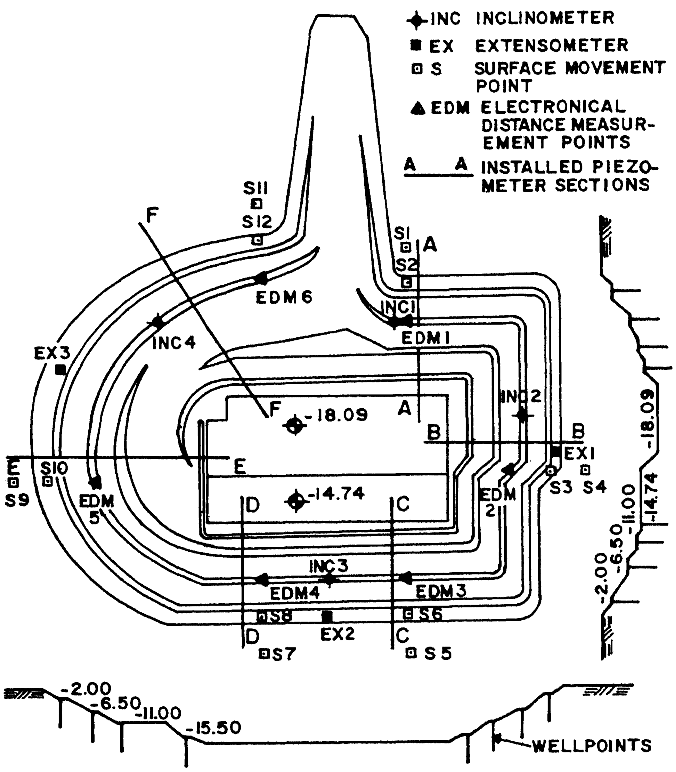

Fig.3. Site Plan of the Excavation Showing the Basement Levels, Stages and Locations of the Dewatering Instruments.

2.3 Estimation of the Quantity of Water to Be Pumped by Wellpoint Dewatering System

The total amount of water pumped from the excavation has been calculated through sections AA-CC and BB-EE (Fig.3), since these two sections are the most representative ones showing the cross-section of the excavation.

The excavation for the pump station construction has an irregular shape, shown in Fig.3. This excavation is approximated to a rectangular shape of the dimensions 120 m x 160 m at the ground level, and 55 m x 95 m at the base.

This excavation can be assumed like a big circular partially penetrating combined artesian -gravity well with the aquifer thickness of 16 meters. The theoretical discharge rates are calculated on the basis of plausible drawdown values in "the big treated well" assumption (Cedergren, 1977). The drawdown values are specified by the wellpoint installation elevations and locations of the wellpoints in the area. If such a well fully penetrates into the pervious stratum, the flow from it can be computed from the following expression developed by Muskat(1962)

$$Q = \frac{\pi k(2bH - b^2 - h_o^2)}{2.3 \log_{10}(R/r_o)} \qquad (1)$$

where Q : discharge rate, (total volume of water), in m^3/day
k : permeability, in m/day
H : thickness of water bearing stratum at a radial distance R from the center of the well, drawdown is zero at this distance, in m.
h_o: thickness of water bearing stratum at the edge of the hole, which has an average (equivalent) radius r_o, calculated from equal area principle as;

$$r_o = \sqrt{\frac{a\,b}{\pi}} \qquad (2)$$

a and b are the dimensions of the excavation, in m
R : radius of influence, in m, estimated from the equation (3) developed by Sichardt, (1930).

$$R = C(H - h_o)\sqrt{k} \qquad (3)$$

where; C is a factor equal to 3000 for radial flow to a pumped well, and equal to 1500-2000 for line of flow to trenches or to a line of wellpoints.

If the screen of a combined artesian-gravity well does not fully penetrate into the pervious stratum, the pattern of the flow will deviate from that of a fully penetrating well. Therefore, the flow required to produce a given drawdown at the well depends upon the depth of the well screen which penetrates into the pervious stratum. The equation for flow to a partially penetrating combined artesian-gravity well is as follows;

$$Q = \frac{\pi k(2bH - b^2 - h_o^2)}{2.3 \log_{10}(R/r_o)} \cdot G \qquad (4)$$

G is the correction factor for partial penetration which is equal to the ratio of flow from a partially penetrating well to that for a fully penetrating well for the same drawdown ($H-h_o$) at the periphery of the well.

There is no available method to calculate the value of G, partial penetration ratio, for partially penetrating wells. Therefore, the flow calculations have been done for fully penetrating combined artesian-gravity well using Equation(1).

The dates, on which the wellpoints in each stage of the excavation were installed and operated are known. Then, the dewatering time of the excavation is divided into four periods. In period I, only the first stage wellpoints are operating in period II, both first and second stages, in period III, first, second and third stages and in period IV, all of the four stages are operating (Fig.4). The actual daily total discharge rates of these four periods were measured at the site using large tanks.

Calculations have been performed using Equation (1) for each stage of the wellpoints for the first and final days of the four periods of dewatering and results are given in Table 3.

TABLE 3. Results of the Analysis from the Fully Penetrating Artesian-Gravity Well Formula

Periods		I	II	III	IV
H(m)		22.8	22.8	22.8	22.8
h_o(m)	First Days	17.8	11.5	7	3
	Final Days	14.8	8.5	4	1
R(m)	First Days	104.2	235.6	329.4	412.8
	Final Days	166.8	298.1	392.0	454.5
r_o(m)		73.0	62.2	50.4	40.8
Q(m^3/hr)	First Days	240.9	140.2	123.7	109.8
	Final Days	168.4	140.1	122.0	107.2

3. Comparison of Actual Flow Rates with the Theoretical Approaches

The theoretical flow rates have been calculated using Equation (1) for the fully penetrating combined artesian-gravity well. Actual flow rates of the dewatered excavation were recorded daily using large storage tanks. The partial penetration ratio, G has been estimated from the comparison of the results obtained from well formulation with actual flow rates.

In Fig.4, the estimated flow rates from the fully penetrating artesian-gravity well formula are plotted in time (days) passed during dewatering. The actual values of the discharge rates measured at the site are also shown in Fig.4.

From Fig.4, it is seen that fully-penetrating artesian-gravity well formula (Eqn.1), overestimates the daily total discharge rates.

As discussed in Section 2.3, this excavation has been treated as a large circular partially penetrating combined artesian-gravity well.

While estimating the quantity of water entering into dewatered excavation, the well formula fo fully penetrating artesian-gravity well is used It is seen, from Fig.4. that the results of th fully penetrating well formula overestimate the discharge rate by a factor of approximately 1.67 This difference is due to the well deviating from the fully penetrating condition. Therefor the partial penetration ratio G, for combined artesian-gravity well can be found as 0.60 .

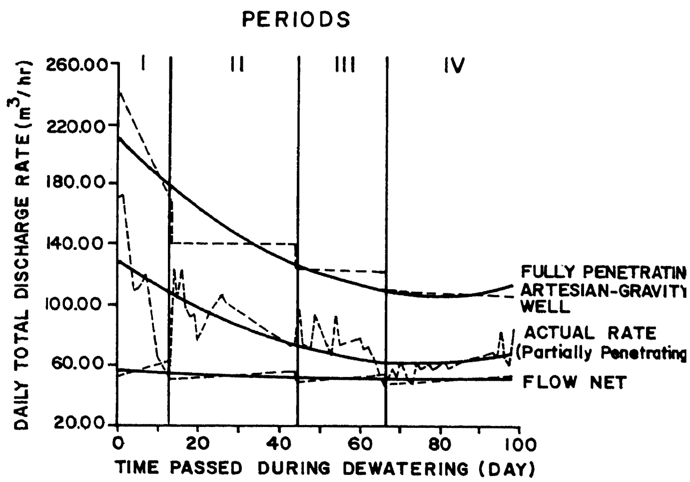

Fig. 4. Comparison of the Actual Discharge Rates with the Theoretical Approaches

The total discharge rates have also been estimated by drawing two-dimensional flow nets and equipotential lines for the excavation. The calculations and figures are not given in detail here. But, it is seen from Fig.4. that flow net analysis gives good results for the periods for which the steady state conditions are attained, i.e. the final days of the dewatering periods.

4. CONCLUSION

The most important factor in the design of wellpoint dewatering system is the coefficient of field permeability. Therefore, for large and important projects field pumping test must be performed to estimate the coefficient of field permeability, as accurate as possible.

Estimation of the daily total discharge rate using the artesian-gravity well formula gives greater values than the actual rates in this case

If a large scale and deep excavation with the confined aquifer condition is to be made by multi-stage wellpoint dewatering system, the partially penetrating artesian-gravity well formula can be used with a G value of 0.60 .

To determine the required number and spacing of wellpoints for a specified drawdown, amount of total discharge rate must be estimated from the proper well formula and then the number of wellpoints should be estimated by dividing the estimated total discharge rate to the capacity of a wellpoint. The capacity of a wellpoint in a soil of specific average permeability is usually recommended by the manufacturer.

Designing the number and spacing of wellpoints by calculating total discharge rate according to either well formula or flow net analysis will give the necessary number of wellpoints to obtain the required drawdown, but with these number of wellpoints the ground water level will be drawn down in a relatively long time. On the other hand, wellpoints designed using nomograms will draw water table down in comparatively shorter times.

REFERENCES

Cedergren, H.R. (1977), "Seepage, Drainage and Flow Nets", John Wiley and Sons, Sacramento-California.

İzmir Sewerage Project, Main Interceptor Section, Çigli to W.W.T.P. and Çigli Pump Station, Geotechnical Data, (1989), Black and Veatch International in Association with Su-Yapı Consulting Engineers.

Mansur, G.P., and Kaufmann, R.I.(1962), "Dewatering, Chapter 3, in Foundation Engineering by Leonards", Mc Graw-Hill, New York.